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Effect of varying moisture regimes and row ratios on yield and economics of chickpea (*Cicer arietinum* L.) and chandrasur (*Lepidium sativum* L.) intercropping systems

Mahanand Sahu, KL Nandeha, YK Devangan, Satyanarayan Singh and Ravishankar Guruwansh

Abstract
A field experiment was carried out during *rabi* season of 2020-21 and 2021-22 in the Instructional-cum-Research Farm, I.G.K.V, Raipur, Chhattisgarh, to study the assessment of chickpea (*Cicer arietinum* L.)-chandrasur (*Lepidium sativum* L.) intercropping productivity using competitive indices under varying moisture regimes. The experiment was laid out in split plot design with three replications with keeping three moisture regimes *viz*., no irrigation (I_0), one irrigation at 35 DAS (I_1) and two irrigations at 35 and 70 DAS (I_2) as main plot and six intercropping systems *viz*., sole chickpea, sole chandrasur, chickpea + chandrasur (1:1), chickpea + chandrasur (2:1), chickpea + chandrasur (3:1) and chickpea + chandrasur (2:2) as sub plot treatments. The application of two irrigations at 35 and 70 DAS (I_2) recorded the highest seed yield, stover yield and biological yield as compared to one irrigation at 35 DAS and no irrigation. Sole chickpea and sole chandrasur gave significantly higher yield as compared to intercropping ratios. The intercropping of chickpea and chandrasur in 3:1 row ratio was significantly superior as compared to sole in terms of gross return, net return and chickpea equivalent yield while, in case of B: C ratio higher was recorded under 2:2 row ratio.

Keywords: Chickpea + chandrasur, economics, competition indices, intercropping, irrigation and yield

Introduction
The most important winter season pulse crop is chickpea (*Cicer arietinum* L.). It is a protein source and plays an important role in human nutrition for a large portion of the world's population. In India, chickpea occupies an area of 9996 thousand ha with a production of 11911 thousand tonnes with an average national productivity of 1192 kg ha^{-1} (Anonymous, 2020-21a) [2]. Chickpea is important pulse crop mostly grown in Maharashtra, Madhya Pradesh, Rajasthan, Gujarat, Karnataka, Uttar Pradesh, Andhra Pradesh and which together contributes about 95% area. In Chhattisgarh, chickpea occupies an area of 301.59 thousand ha with a production of 267.51 thousand tonnes and average productivity of 887 kg ha^{-1} (Anonymous, 2020-21b) [3]. Chandrasur (*Lepidium sativum* L.) it is known as *chandrasur* in Hindi, Its English name is Garden cress which belongs to family Brassicaceae. The states of Uttar Pradesh, Madhya Pradesh, Rajasthan, Gujarat, and Maharashtra are the primary producers of garden cress. In India, with an annual production of medicinal and aromatic plant is 605000 million tons (Anonymous, 2011) [1]. In India, a medicinal and aromatic plant grown is spread across the states of Rajasthan, Madhya Pradesh, Uttar Pradesh, Gujarat, and Maharashtra in an area of about 5,000 hectares (Choudhary *et al*., 2010) [4].
Chickpea is commonly grown in conserved soil moisture during *rabi* season. Though the water requirement of chickpea is less, it responds well to irrigation. Inadequate soil moisture is a major constraint to crop productivity. So, irrigation is essential for increasing yield (Singh *et al.*, 2015a) [15]. Irrigation improved the nodulation and increased the per plant yield by increasing the pod number (Kaul, 1976) [7]. The primary goal of intercropping is to increase total productivity per unit area of land per unit time by growing more than one crop in the same field, with the primary goal being improved environmental resource utilization. Intercropping is primarily used to mitigate the risk of total failure of one of the component crops due to weather or pest and disease incidence (Singh and Katyal, 1966) [16]. Intercropping, not only stabilizes crop yield by reducing the impact of weather vagaries, but also significantly increases cropping intensity (Sarkar and Shit, 1990) [13].

Diversification of cropping systems is necessary to get higher yield and restoration to maintain soil health, sustain the environment and meet food for human and animal for daily requirement and future generation. Given the growing demand for chickpea and chandrasur to increase production and acreage, the plant's soil moisture regimes and intercropping system will have a significant impact on chickpea and chandrasur productivity, but no research has been done to quantify the effects of varying moisture regimes and intercropping systems. Hence, an experiment was conducted to study on chickpea-chandrasur intercropping system under varying moisture regimes was undertaken with an object to find out most efficient intercropping system for obtaining higher system productivity under varying moisture regimes and select the suitable intercropping evaluation indices in this system.

Materials and Methods

The Raipur experimental site was conducted during *rabi* season of 2020-21 and 2021-22 in the south-eastern part of Chhattisgarh the location of the experimental site is Instructional-cum-Research Farm, I.G.K.V, Raipur, Chhattisgarh. Raipur (Chhattisgarh) it is located at 21°4 ' N latitude and 81 °39 ' E longitude at an altitude of 298 meters above sea level with sub-humid climate. The soil of experimental site was sandy clay loam in texture and neutral in reaction, medium in organic carbon content, low in available nitrogen and medium in available phosphorus and available potash. The total rainfall received during the cropping season of *rabi* 2020-21 and 2021-22 was 7.4 mm and 107.4 mm, respectively. The experiment was laid out in split plot design with three replications with keeping three moisture regimes *viz*., no irrigation (I_0), one irrigation at 35 DAS (I_1) and two irrigations at 35 and 70 DAS (I_2) as main plot and six intercropping systems *viz*., sole chickpea, sole chandrasur, chickpea + chandrasur (1:1), chickpea + chandrasur (2:1), chickpea + chandrasur (3:1) and chickpea + chandrasur (2:2) as sub plot treatments. The cultivars used in the study were Indira Chana-1 (chickpea) and GA-1 (chandrasur). The recommended seed rates were 80 kg ha^{-1} for chickpea and 8 kg ha^{-1} for chandrasur. The crops were sown during the 12th November 2020 and 26th November 2021, respectively. The recommended dose of fertilizer for chickpea and chandrasur were 20, 50 and 20 kg NPK ha^{-1} and 60, 40 and 30 kg NPK ha^{-1} respectively. All the recommended fertilizer for chickpea was applied at the time of sowing. Half dose of N and full dose of P and K were applied for chandrasur. Nitrogen, phosphorus and potash were applied at the form of urea, single super phosphate and muriate of potash. In case of intercropping treatment, fertilizers were applied in proportionate to the sole optimum population for main crop and intercrop, separately. The crop of chickpea and chandrasur were sown at a row spacing of 30 cm in sole as well as intercropping system. It was a replacement series of intercropping system.

The data obtained on growth and yield was statistically analyzed for computing the critical difference (CD) at 5% significant level as per the technique commonly used for split plot design (Gomez and Gomez, 1984). For assessing the economic viability of the system, land use and production efficiency were computed by using the formulae-

Results and Discussion

Effect of yields on moisture regimes

The data pertaining to the chickpea seed yield, stover yield and biological yield significantly affected by varying moisture regimes The seed yield, stover yield and biological yield of chickpea due to I_2 (two irrigations at 35 DAS and 70 DAS) recorded significantly highest seed yield followed by I_1 (one irrigation at 35 DAS during 2020-21, 2021-22 and on a mean basis, respectively. The lowest seed yield, stover yield and biological yield was recorded when no irrigation (I_0) was applied during both the years of experimentation and on a mean basis, respectively.

The increases in seed yield under two irrigations (35 DAS and 70 DAS) (I_2) may be attributed to timely and adequate moisture availability which helped proper utilization of nutrients and also better formulation and accumulation of photosynthates. The results collaborated with Parihar and Tripathi (1989) [11]. The reasons behind these results might be due to adequate moisture supply throughout the entire crop growth period, which results in to better growth and development. Similar results were confirmed by Mhaske *et al*. (2019) [10] who revealed that, irrigation each at 50% branching and pod development stages is produced maximum stover yield over no irrigation and one irrigation at 50% branching. The Chickpea equivalent yield (CEY) was increased significantly with increasing irrigation levels. Application of two irrigations at 35 and 70 DAS (I_2) recorded the maximum chickpea equivalent yield (2186.39, 2064.38 and 2125.38 kg ha^{-1}), followed by one irrigation at 35 DAS (I_1) (1871.95, 1739.10 and 1805.53 kg ha^{-1}) during both the year of experimentations and on a mean basis, respectively. The lowest chickpea equivalent yield (1448.48, 1504.84 and 1476.66 kg ha^{-1}) was recorded under no irrigation (I_0). The improvement in chickpea equivalent yield (CEY) may be attributed to timely and sufficient moisture availability that aided in optimal nutrient usage as well as enhanced formulation and photosynthate accumulation. The results are supported by the findings of Parihar and Tripathi (1989) [11].

Effect of intercropping system on yield of component crops

The maximum seed yield (1525.01, 1347.37 and 1436.19 kg ha^{-1}) of chickpea was recorded under pure stand and it was significantly superior over the other treatments, followed by 3:1 row ratio of chickpea + chandrasur during both the years of experimentation and on a mean basis, respectively. However, the lowest seed yield (941.69, 760.00 and 850.84 kg ha^{-1}) of chickpea was observed in 1:1 row ratio of chickpea + chandrasur during both the years of investigation and on a mean basis, respectively. According to Das *et al*. (2017) [9], a sole crop of chickpea and rapeseed outperformed intercropping systems in terms of yield and yield attributes. Chickpea grown in a 3:1 row ratio with rapeseed recorded significantly more pods $plant^{-1}$, seeds pod^{-1} and 1,000-grain weight, as well as greater seed yield. The results are in confirmation with Yadav *et al*. (2018) [18], Gobade *et al*. (2015) [6], Parihar *et al*. (2000) [12], and Kulmi and Chundawat (1997) [8]. The maximum stover yield (2190.76, 1967.09 and 2078.92 kg ha^{-1}) of chickpea was recorded under pure stand and it was significantly superior over the other treatments, which was found at par with 3:1 row ratio of chickpea +

chandrasur during both the years of experimentations and on mean basis, respectively. However, the lowest stover yield (1648.50, 1356.06 and 1502.28 kg ha^{-1}) of chickpea was observed in 1:1 row ratio of chickpea + chandrasur during both the years of investigation and on mean basis, respectively. These results are confirmed by Das *et al*. (2017) [9], Gobade *et al*. (2015) [6] in the instance of chickpea, a sole crop produced highest straw yield than an intercropping with safflower. The highest CEY was recorded under the 3:1 row ratio of chickpea + chandrasur (2223.46, 2082.59 and 2153.03 kg ha^{-1}) during both the year of experimentations and on mean basis which was followed by 2:1 (2054.93, 1872.49 and 2013.71 kg ha^{-1}), 2:2 (2047.77, 1916.84 and 1982.31 kg ha^{-1}) and 1:1 (2006.01, 2047.17 and 2026.59 kg ha^{-1}) row ratios of chickpea + chandrasur association during 2020-21 and during 2021-22. The lowest chickpea equivalent yield (1525.01, 1347.37 and 1436.19 kg ha^{-1}) was recorded in sole chandrasur. Among intercropping systems, the row proportion of 3:1 (chickpea + chandrasur) was found superior. This was due to better yields and good prevailing market prices coupled with better utilization of resources by the component crops in the intercropping system. Similar results were also observed by Gupta *et al*. (2019) who founded maximum pooled chickpea equivalent yield under chickpea + linseed in 5:1 row ratio as compared to sole chickpea and sole linseed.

Effect of moisture regimes on economics of component crops

The results of analysis of variance made it clear that among moisture regimes, I_2 (two irrigations at 35 and 70 DAS) reflected in the highest gross returns and net return during 2020-21, 2021-22 and on mean basis, respectively) as compared to I_1 (one irrigation at 35 DAS) during 2020-21, 2021-22 and on mean basis, respectively) and no irrigation during 2020-21, 2021-22 and on mean basis, respectively). These results confirmed the findings of Lende and Patil (2017) [9] where irrigation scheduling at branching and pod development stage with all furrows irrigated recorded higher gross monetary return (Rs. 82558 ha^{-1}) than rest of the treatments. These results are confirmed by Basha *et al*. (2020) according to them, when irrigation was applied, there were more net returns (Rs 46,768 ha^{-1}) than when irrigation was not applied (Rs 30,795 ha^{-1}). Statistically the highest B: C ratio (3.34, 3.19 and 3.26 during 2020-21, 2021-22 and on mean basis, respectively) was obtained from I_2 (two irrigations at 35 and 70 DAS) which were found significantly superior over I_1 (one irrigation at 35 DAS) having the B: C ratios of 3.05, 2.87 and 2.96 during 2020-21, 2021-22 and on mean basis, respectively.

Effect of intercropping system on economics of component crops

Significant differences in gross returns and net return were noted due to different intercropping ratios in both the years 2020-21, 2021-22 and their mean basis. Maximum gross return and net return was obtained under the intercropping ratio C_5 (3:1 row ratio of chickpea + chandrasur) found to be significantly superior over other intercropping ratios. Sole stand of chickpea *i.e*., C_1 gave the lowest gross returns and net return. These might be due to higher chickpea equivalent yield and good prevailing market prices. These results confirmed the findings of Sharma and Goswami (2010) [14] who found that 4:1 row proportion of chickpea and linseed gave the highest net profit of (Rs. 15285 ha^{-1}). Significant differences in B: C ratio was recorded with varying row ratio of intercropping in both the years of experimentation and their mean basis. Intercropping ratio of 2:2 (chickpea + chandrasur) *i.e*., C_6 had recorded highest B: C ratio (3.40, 3.21 and 3.31 during 2020-21, 2021-22 and on mean basis, respectively). These results confirm the findings of Singh *et al*. (2019) [17] who found that, treatment combinations of 4:1 (4 row chickpea+ 1 row mustard) had the highest benefit: cost ratio when compared to sole stand.

Table 1: Yield of chickpea as influenced by chandrasur intercropping under varying moisture regimes

	Yield								
	Seed yield (kg ha^{-1})			Stover yield (kg ha^{-1})			Biological yield (kg ha^{-1})		
Treatment	**2020-21**	**2021-22**	**Mean**	**2020-21**	**2021-22**	**Mean**	**2020-21**	**2021-22**	**Mean**
Moisture regimes									
I_0 - No irrigation	996.17	895.00	945.59	1764.37	1488.29	1626.33	2760.54	2383.29	2571.92
I_1 - One irrigation at 35 DAS	1266.69	1013.80	1140.25	1976.33	1612.36	1794.35	3243.03	2626.17	2934.60
I_2 - Two irrigation at 35 and 70 DAS	1491.47	1202.83	1347.15	2161.49	1800.75	1981.12	3652.96	3003.58	3328.27
S.Em±	13.57	23.40	11.56	59.27	52.51	54.31	66.92	58.73	63.02
CD (P=0.05)	53.28	91.87	45.40	232.73	206.20	213.24	262.78	230.60	247.46
Intercropping systems									
C_1 - Chickpea sole	1525.01	1347.37	1436.19	2190.76	1967.09	2078.92	3715.77	3314.46	3315.12
C_2 - Chandrasur sole	-	-	-	-	-	-	-	-	-
C_3 - Chickpea + Chandrasur (1:1)	941.69	760.00	850.84	1648.50	1356.06	1502.28	2590.19	2116.06	2353.12
C_4 - Chickpea + Chandrasur (2:1)	1245.58	1027.88	1136.73	2054.44	1624.32	1839.38	3300.02	2652.20	2976.11
C_5 - Chickpea + Chandrasur (3:1)	1385.83	1142.36	1264.10	2116.81	1755.24	1936.03	3502.65	2897.60	3200.12
C_6 - Chickpea + Chandrasur (2:2)	1159.12	908.45	1033.78	1826.49	1466.30	1646.39	2985.61	2374.75	2680.18
S.Em±	38.56	35.42	28.06	79.12	79.68	66.13	98.67	101.21	77.76
CD (P=0.05)	112.54	103.39	81.90	230.92	232.58	193.02	288.00	295.42	226.96
Interaction (I×C)	NS	NS	NS	NS	NS	NS	NS	NS	NS

Table 2: Yield of chandrasur as influenced by chickpea intercropping under varying moisture regimes

	Yield of chandrasur								
	Seed yield (kg ha^{-1})			Stover yield (kg ha^{-1})			Biological yield (kg ha^{-1})		
Treatment	**2020-21**	**2021-22**	**Mean**	**2020-21**	**2021-22**	**Mean**	**2020-21**	**2021-22**	**Mean**
Moisture regimes									
I_0	496.74	664.38	580.56	1336.43	1660.72	1498.58	1833.17	2325.10	2079.13
I_1	656.76	795.49	726.13	1582.25	1923.80	1753.02	2239.01	2719.29	2479.15
I_2	762.97	944.83	853.90	1793.92	2193.76	1993.84	2556.89	3138.59	2847.74
S.Em±	23.98	23.93	20.40	54.35	51.85	46.75	78.28	75.17	66.94
CD (P=0.05)	94.15	93.95	80.08	213.41	203.58	183.56	307.36	295.16	262.83
Intercropping systems									
C_1	-	-	-	-	-	-	-	-	-
C_2	1156.45	1250.17	1203.31	2689.66	2879.83	2784.75	3846.11	4130.00	3988.06
C_3	688.19	923.96	806.07	1648.73	2208.03	1928.38	2336.92	3131.99	2734.45
C_4	424.06	594.65	509.35	1140.06	1490.73	1315.39	1564.11	2085.38	1824.75
C_5	420.73	570.74	495.73	1095.57	1378.16	1236.86	1516.29	1948.90	1732.60
C_6	504.69	668.31	586.50	1280.32	1673.70	1477.01	1785.01	2342.01	2063.51
S.Em±	20.59	31.83	18.98	57.12	55.03	43.97	75.69	85.55	61.78
CD (P=0.05)	60.09	92.89	55.40	166.73	160.61	128.35	220.92	249.70	180.33
Interaction (I×C)	S	S	S	S	S	S	S	S	S

Moisture regimes: I_0 - No irrigation, I_1 - One irrigation at 35 DAS, I_2 - Two irrigation at 35 and 70 DAS
Intercropping systems: C_1 - Chickpea sole, C_2 - Chandrasur sole, C_3 - Chickpea + Chandrasur (1:1), C_4 - Chickpea + Chandrasur (2:1), C_5 - Chickpea + Chandrasur (3:1), C_6 - Chickpea + Chandrasur (2:2)

Table 3: Economics of chandrasur intercropping in chickpea under varying moisture regimes

Treatment	Cost of cultivation (Rs ha^{-1})			Gross return (Rs ha^{-1})			Net return (Rs ha^{-1})			B:C Ratio		
	2020-21	**2021-22**	**Mean**	**2020-21**	**2021-22**	**Mean**	**2020-21**	**2021-22**	**Mean**	**2020-21**	**2021-22**	**Mean**
Moisture regimes												
I_0	28480	29668	29074	72261	78553	75407	43782	48886	46334	2.53	2.64	2.59
I_1	30560	31748	31154	93461	91034	92247	62901	59286	61094	3.05	2.87	2.96
I_2	32640	33828	33234	109240	108013	108627	76601	74186	75393	3.34	3.19	3.26
S.Em±	-	-	-	1072	1918	1449	1072	1918	1449	0.03	0.06	0.05
CD (P=0.05)	-	-	-	4209	7529	5688	4209	7529	5688	0.13	0.24	0.18
Intercropping systems												
C_1	31048	32236	31642	74344	68716	71530	43296	36480	39888	2.38	2.12	2.25
C_2	26732	27920	27326	69387	77510	73449	42655	49591	46123	2.58	2.76	2.67
C_3	32115	33303	32709	97793	104405	101099	65678	71102	68390	3.02	3.13	3.08
C_4	32174	33362	32768	100178	100597	100387	68004	67235	67619	3.10	3.01	3.05
C_5	32229	33417	32823	108394	106212	107303	76164	72795	74480	3.35	3.16	3.25
C_6	29059	30247	29653	99829	97759	98794	70770	67512	69141	3.40	3.21	3.31
S.Em±	-	-	-	2669	2557	1765	2669	2557	1765	0.08	0.08	0.06
CD (P=0.05)	-	-	-	7710	7384	5096	7710	7384	5096	0.24	0.24	0.16
Interaction (I×C)	-	-	-	NS	NS	NS	NS	NS	NS	NS	NS	NS

Moisture regimes: I_0 - No irrigation, I_1 - One irrigation at 35 DAS, I_2 - Two irrigation at 35 and 70 DAS
Intercropping ratios: C_1 - Chickpea sole, C_2 - Chandrasur sole, C_3 - Chickpea + Chandrasur (1:1), C_4 - Chickpea + Chandrasur (2:1), C_5 - Chickpea + Chandrasur (3:1), C_6 - Chickpea + Chandrasur (2:2).

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